

REMARKS

By the present amendment, claims 1 and 27 to 30 are pending in the application.

Restriction Requirement

The Office Action imposed a restriction requirement and withdrew claims 15 to 26 from consideration as being directed to a non-elected invention.

In response to the restriction requirement, non-elected claims 15 to 26 have been canceled by the present amendment. Claims 15 to 26 have been canceled without prejudice to the filing of a divisional application directed to claims 15 to 26.

Claim Amendments

Claim 1

Support for the new limitations added to claim 1 is as follows.

Prior dependent claim 5 supports the presence of Ni; the weight percent range of Ni; the relationship among Si, Al and Ni; the expressions directed to Si and Al and directed to Ni, Si, and Al; and retained austenite in the range of 2 to 20%.

Prior dependent claim 14 supports the maximum length of the Si, Mn and Al oxides and the gaps between the oxides.

Claim 27

Support for new dependent claim 27 is as follows.

Prior dependent claim 5 supports the Cr and Mo, the weight percent ranges, and the relationship between Ni and Mo.

Claim 28

Support for new dependent claim 28 is as follows.

Prior dependent claim 6 supports Cu and Sn; the weight percent ranges; the relationship among Ni, Cu and Sn; and the relationship among Si, Al, Ni, Cu and Sn.

Claims 29 and 30

Support for new dependent claims 29 and 30 is as follows.

Prior dependent claim 4 supports V, Ti, Nb, B, REM, Ca, Zr, Mg and the weight percent ranges.

§102

Claims 1, 2, 4-6 and 14 were rejected under 35 U.S.C. §102(b) as being anticipated by WO 02/101112 to Fujita et al.

This rejection, as applied to the amended and new claims, is respectfully traversed.

The Present Invention

The present invention is directed to a high-strength hot-dip galvanized steel sheet. The high-strength hot-dip galvanized steel sheet of the present invention is produced by a method comprising the steps of:

providing a hot-rolled and cold-rolled steel sheet, with the steel sheet containing, in weight,

C: 0.03 to 0.25%,

Si: 0.05 to 2.0%,

Mn: 0.5 to 2.5%,

P: 0.03% or less,

S: 0.02% or less,

Al: 0.01 to 2.0%, and

Ni: 0.01 to 2.0%,

balance Fe and unavoidable impurities;

with the relationship among Si, Mn, Al and the relationship among Si, Al and Ni satisfying the following expressions,

$$\text{Si} + \text{Al} + \text{Mn} \geq 1.0\%,$$

$$0.4 (\%) \leq \text{Si} (\%) + \text{Al} (\%) \leq 2.0 (\%),$$

$$\text{Ni} (\%) \geq 1/5 \times \text{Si} (\%) + 1/10 \times \text{Al} (\%);$$

and said steel sheet contains retained austenite in the range from 2 to 20%,
annealing said hot-rolled and cold-rolled steel sheet for 10 sec. to 6 min. in a dual phase coexisting temperature range of 750°C to 900°C;

subsequently cooling said annealed steel sheet to 350°C to 500°C at a cooling rate of 2 to 200°C/sec.;

hot-dip galvanizing said cooled steel sheet to form a hot-dip galvanizing layer on each surface of said steel sheet;

cooling said hot-dip galvanized steel sheet to 250°C or lower at a cooling rate of 5°C/sec. or more;

wherein 5 to 80% of the surface area of said steel sheet is being occupied by Si, Mn and Al oxides when said steel sheet surface is observed with a scanning electron microscope after the hot-dip plating layer is dissolved by fuming nitric acid;

and wherein said surface area of said steel sheet occupied by said Si, Mn and Al oxides is on the surfaces of said steel sheet interfacing with the hot-dip plating layer prior to the hot-dip plating layer being dissolved by the fuming nitric acid;

and wherein said Si, Mn and Al oxides have a maximum length of 3μm and said Si, Mn and Al oxides have gaps between them.

Patentability

The Office Action maintains that the steel sheets of Fujita contain the claimed amounts of Si, Al and Mn oxides notwithstanding their presence at grain boundaries. The

Office Action maintains that the layer containing the oxides is on a steel surface even though the layer with oxides also contains some steel material, and further maintains that with respect to prior dependent claim 14, the thickness of the oxides layer may be less than 3 μ m, and in addition to grain interfacial zones, the steel material lacking oxide may constitute the claimed gaps between oxides.

The applicants submit that the positions maintained by the Office Action are incorrect. Fujita does not disclose or suggest the form of oxides and a controlling of the oxide formation in accordance with the present invention. Further, the oxides disclosed in Fujita are quite difference from the oxides according to the present invention.

There are several disclosures regarding the oxides in Fujita which are as follows.

1) The maximum depth of the grain boundary oxidized layer formed at the interface is not more than 0.5 μ m (claim 1 of Fujita).

2) The maximum depth of the grain boundary oxidized layer formed at the interface is not more than 1 μ m, and the average grain size of the main phase in the microstructure of the base layer is not more than 20 μ m (claim 2 of Fujita).

3) The value obtained by dividing the maximum depth of the grain boundary oxidized layer formed at the interface between the plated layer and the base layer by the average grain size of the main phase in the microstructure of the base layer is not more than 0.1 (claim 3 of Fujita).

4) The steel contains one or more of SiO₂, MnO and Al₂O₃ at 0.1 to 70% in total area percentage in the range from the interface between the plated layer and the steel sheet to the depth of 10 μ m, and satisfy the equation; $(\text{MnO} + \text{Al}_2\text{O}_3/\text{SiO}_2) \geq 0.1$ (claim 28 of Fujita).

5) The steel contains one or more of Y_2O_3 , ZrO_2 , HfO_2 , TiO_3 , La_2O_3 , Ce_2O_3 , CeO_2 , CaO and MgO at 0.0001 to 10.0% in total area percentage in the range from the interface between the plated layer and the steel sheet to the depth of 10 μm (claim 29 of Fujita).

As described above, Fujita only mentions the importance of the maximum depth of the grain boundary oxidized layer, and the total area percentage depth of 10 μm regarding the amount of oxides. However, Fujita does not disclose or suggest the ratio of the surface area of the oxide layer at the interface between the plated layer and the base steel sheet. The area ratio disclosed in Fujita is considered to be lower SiO_2 , as mentioned in the expression of $(\text{MnO} + \text{Al}_2\text{O}_3/\text{SiO}_2) \geq 0.1$. On the other hand, in the present invention, the characteristic feature is the amount of all of oxides and control of the oxide formation, and there is no restriction of the kind of oxides and the constitutional ratio of oxides.

Regarding the microstructure of the surface layer, Fujita discloses the following.

1) Si system oxides were observed at the grain boundaries of the interface between the plated layer and the base layer, and high fatigue and corrosion resistance can be obtained by controlling the maximum depth of the grain boundary oxidized layer of not more than 0.5 μm , preferably not more than 0.2 μm , and selecting the steel components and the production conditions.

2) Restricting the kinds and area percentage of oxides in a steel, which contained grain boundary oxides in the range from the interface between the plated layer and the steel sheet to the depth of 10 μm , for increasing fatigue and corrosion resistance after an alloying treatment.

In addition, Fujita discloses the following regarding obtaining such oxides at the grain boundaries.

1) For securing oxides at an interface in the required amount, it is desirable to control the temperature and working history from the hot-rolling stage, such as slab heating temperature, the reduction rate, the finishing temperature, and the coiling temperature, and the same time, to leave elements such as Ti, Al, etc. in a solid solution state.

2) It is desirable to remove a oxide layer formed during hot-rolling as much as possible by employing a high-pressure descaling or a heavy pickling after the finish rolling.

3) It is desirable to control the cold-rolling reduction rate to not less than 30% using rolls not more than 1,000 mm in diameter for breaking oxides.

4) In annealing, it is desirable to heat a steel sheet at the rate of 5°C/sec. up to the temperature range of not less than 750°C for the purpose of accelerating the formation of other oxides by suppressing the formation of SiO₂.

As mentioned above, Fujita notes a relationship between the grain boundary oxidation and fatigue and corrosion resistance. For this purpose, Fujita is only limited to contain oxides at the grain boundaries and the kinds of oxides and the area percentage in the range from the interface between the plated layer and the steel sheet to the depth of 10 μm. In addition, Fujita does not disclose or suggest the annealing conditions before plating. As described above, Fujita does not disclose or suggest the characteristic feature of the present invention in the points of the formation of oxides and their control.

Furthermore, the present invention discovered with respect to the surface structure of the steel sheet for improving plating that the hot-dip galvanizing ability remarkably improves by obtaining a state of an inner oxidization at the surface of the steel sheet immediately under the hot-dip galvanizing layer. This means that the inner oxides are intentionally formed at the steel sheet surface to secure a sufficient plating at the non-forming oxide portions for reducing concentrations of Si, Mn and Al which prevent plating ability. This feature is quite different from the idea of restraining Si oxidization.

In addition, the present invention defines the Si, Mn and Al oxides having a maximum length of 3 μm and the Si, Mn and Al oxides have gaps between them, as shown in Fig. 2. This feature is also quite different from the oxide layer having a thickness of 3 μm as defined in Fujita.

As was mentioned in the previous argument, Fujita targets to regulate the microstructure of the interface between a plated layer and the steel layer to improve fatigue and corrosion resistance. An improvement to the platability is carried out, according to Fujita, by means of reduction of the Al concentration and adding certain amounts of specific elements into the plating layer, as mentioned in the expressions of 1, 2 and 3, and further defining the relationship between the amounts of Mn, Al and Mo contained in the steel sheet, and the concentration of Al, Mn and Mo contained in the plating layer.

Therefore, Fujita does not disclose or suggest the oxide control on the surface of the steel sheet by means of controlling the atmosphere before plating step, which is the main feature of the present invention. Further, Fujita clearly discloses that fatigue and corrosion resistance properties are improved by means of controlling the depth of oxides phase at the grain boundary and the ratio of oxides at the cross-sectional area in the depth direction from the interface to 10 μm .

On the other hand, the present invention defines the area ratio of oxides on the surface of the steel sheet at the interface between the plating and the surface of the steel sheet, which is quite different from the feature of controlling the depth of the oxide phase at the grain boundary and the ratio of oxides at the cross-sectional area in the depth direction from the interface to 10 μm . Therefore, the present invention is quite different from the technology disclosed or suggested in Fujita.

It is therefore submitted that amended independent claim 1, and all claims dependent thereon, are patentable over Fujita.

CONCLUSION

It is submitted that in view of the present amendment and foregoing remarks, the application is now in condition for allowance. It is therefore respectfully requested that the application, as amended, be allowed and passed for issue.

Respectfully submitted,

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